MEASUREMENT OF SOFTWARE SIZE: CONTRIBUTIONS OF COSMIC TO ESTIMATION IMPROVEMENTS

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Presenter background: Alain Abran

20 years

- Development
- Maintenance
- Process Improvement

+ 35 PhD

ISO: 19761, 9216, 25000, 15939, 14143, 19759

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ICEAA Bristol (UK), Oct. 2016
Agenda

- Background to Functional Size Measurement (FSM) methods
- COSMIC Method — Key features of ISO 19761
- Measurement Guidelines
- ‘The proof of the pudding is in the eating’: Good Estimation
- Automation of COSMIC measurement
- Conclusions
Objective: we want to use performance data for estimating future projects
Software Sizing Options

Sizing method options:

- **Lines of code:**
  - X Can’t estimate until software designed
  - X Technology-dependent, no standards

- **Usecase Points, Object Points:**
  - X Technology dependent, no standards,
  - X Mathematically invalid?

- **Story Points (Planning Poker):**
  - X Entirely Subjective & Benchmarking impossible:
    - ▶ unaccountability

- **Functional size**
  - ✓ International standard methods
  - ✓ Technology-independent
Function Points have been around for a long time: + 35 years!
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Key Concepts of Measurements

- Measurement of what is common
  - not what is different: measurement of a single concept independent of contexts

- Measurement standards – for all people

- Standard Unit of measurement (‘étalon’) to ensure consistency-repeatability-reproducibility, etc.

- Measuring instruments:
  - Manual – procedures & guidelines
  - Partially or Totally automated with measuring instruments

COSMIC Method

- Designed by an international group of software measurement experts
  - COSMIC: Common Software Measurement International Consortium
- To measure the Functional User Requirements of:
  - Business application
  - Real-time
  - Infrastructure software
  - Various other types of software
  - Hybrids of these
- Based on:
  - Metrology
  - Fundamental software engineering principles
- An ISO standard: ISO 19761
- Open, freely available (via www.cosmic-sizing.org)
Software is an ‘intellectual’ product: can we measure it?

- Time: can we ‘see’ or ‘touch’ time?
  ➢ Answer = ............

- Distance: is there a unique distance between 2 cities?
  ➢ Answer = ............

- Do we need to ‘see’ something to measure it?
  ➢ Answer = ............

- Can we measure something before it exists?
  ➢ Answer = ............
Software is an ‘intellectual’ product: can we measure it?

- **Time:** can we ‘see’ or ‘touch’ time?
  - **Answer = No** (...but measuring instruments have been built...)

- **Distance:** is there a unique distance between 2 cities?
  - **Answer: It depends** (by road, by car, by train, by highways, by plane)

- **Do we need to ‘see’ something to measure it?**
  - **Answer = No** (...ex. microscope)

- **Can we measure something before it exists?**
  - **Answer = Yes** (....from their representation in models & plans)
What is common across all software, in different types of software, whether very small or extremely large?
All software does this!

**Functional users**
- Humans
- Other software
- Hardware devices

**Functional process**
- Entry
- Exit
- Read
- Write

**Boundary**
1 entering data group
1 exiting data group
1 retrieved data group
1 data group to be stored

**Persistent storage**
4 types of ‘Data Movement’

Functional Users
• Hardware devices,
• Other software or
• Humans

The ‘Data Movement of 1 data group’ is the unit of measurement: 1 CFP (COSMIC Function Point)
All software Functional User Requirements can be broken down into functional processes.
A Functional Process responds to an ‘Event’ that a ‘Functional User’ detects or generates.
Example: Intruder Alarm System

Input devices (functional users):
- Keypad
- Power voltage detector
- Front door sensor
- Movement detectors

Output devices (functional users):
- External alarm
- Internal alarm
- 2 x LED’s

Software Boundary:
- The embedded alarm software

Persistent storage
# Intruder Alarm System

**Functional process:** Possible intruder detected.  
**Triggering event:** Door opens whilst alarm system is activated.

<table>
<thead>
<tr>
<th>Data Movement</th>
<th>Functional User</th>
<th>Data Group</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Entry</strong></td>
<td>Front-door sensor</td>
<td>‘Door open’ message (triggering Entry)</td>
</tr>
<tr>
<td><strong>Read</strong></td>
<td>-</td>
<td>PIN (from persistent storage)</td>
</tr>
<tr>
<td><strong>Exit</strong></td>
<td>Green LED</td>
<td>Switch ‘off’ command</td>
</tr>
<tr>
<td><strong>Exit</strong></td>
<td>Red LED</td>
<td>Switch ‘on’ command</td>
</tr>
<tr>
<td><strong>Exit</strong></td>
<td>Internal siren</td>
<td>Start noise command</td>
</tr>
<tr>
<td><strong>Entry</strong></td>
<td>Keypad</td>
<td>PIN (If the wrong code is entered, the user may enter the PIN two more times but the process is always the same so it is only measured once.)</td>
</tr>
<tr>
<td>*</td>
<td>Green LED</td>
<td>Switch ‘on’ command (after successful entry of PIN)</td>
</tr>
<tr>
<td>*</td>
<td>Red LED</td>
<td>Switch ‘off’ command</td>
</tr>
<tr>
<td><strong>Exit</strong></td>
<td>Internal siren</td>
<td>Stop noise command (after successful entry of PIN)</td>
</tr>
<tr>
<td><strong>Exit</strong></td>
<td>External siren</td>
<td>Start noise command (after three unsuccessful PIN entries, or if the PIN is not entered in time)</td>
</tr>
<tr>
<td><strong>Exit</strong></td>
<td>External siren</td>
<td>Stop noise command (after 20 minutes, a legal requirement)</td>
</tr>
</tbody>
</table>

Size = 9 CFP

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1st Generation of Function Points: Step Functions!

Function Points (FP)

Key limitations:
- Only 3 values
- Limited ranges (min,max)
- No single measurement unit of 1 FP!

3-step size range for the IFPUG External Input Transactions
2nd Generation with COSMIC

- COSMIC Function Points (CFP)
- No arbitrary max
- A single CFP exists & is well defined
COSMIC sizes are measured on a true ratio scale

- There is no upper limit to the size of a functional process
- Largest observed functional processes?
  - In avionics >100 CFP
- The size of the smallest change to an existing functional process is 1 CFP

- Open, freely available (via www.cosmic-sizing.org)
1st and 2nd Generations of FSM

Function Points (FP)

COSMIC Function Points - CFP

No arbitrary max

A single CFP exists & well defined
1\textsuperscript{st} & 2\textsuperscript{nd} generation of Function Points Methods

1\textsuperscript{st} generation

- Allan Albrecht FPA
- Feature Points
- 3-D FP’s
- MkII FPA

2\textsuperscript{nd} generation

- ISO ‘FSM’ Standard 14143
- COSMIC FFP
- COSMIC v. 4.0.1
- Full FP’s v. 1
- IFPUG 4.1
- IFPUG 4.3
- MkII FPA v.1.3
- IFPUG 4.0
- IFPUG 4.1
- Full FP’s v.1
- MkII FPA v.1.3
- 3-D FP’s
- Feature Points
- Allan Albrecht FPA

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COSMIC - at any level of software requirements

Application Layer

App 1  App 2  App ‘n’

Middleware Layer (Utilities, etc)

Database Management System Layer

DBMS 1  DBMS 2

Operating System Layer

Keyboard Driver  Screen Driver  Print Driver  Disk Driver

Hardware

Keyboard  VDU Screen  Printer  Hard Disk Drive  Central Processor

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There is a well-defined Measurement Process

Input from measurement sponsor

Software Context Model

FUR

Definition of each piece of software to be measured and of the required measurement (Purpose and scope)

Phase 1 Measurement Strategy

Functional User Requirements (FUR) in the local format (text, graphics, etc.)

COSMIC Generic Software Model

Phase 2 Mapping Phase

FUR in the form of the COSMIC Generic Software Model

Phase 3 Measurement Phase

Functional size of the software in units of CFP

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- Conclusions
Recent Guidelines for Practitioners

A Guideline describing a range of Approximate Sizing methods
Size/Cost estimates are usually needed before the FUR have been defined in detail

A Guideline on ‘Assuring the accuracy of COSMIC measurements’
Guidelines by Application Domains

- Business applications
- Real-time software
- Data Warehouse software
- SOA software
- Mobile apps

and for Agile Developments
Aggregation rules for components, sprints, etc. up to whole software systems

COSMIC size measurement is usable for:
- early total System sizing and effort estimation;
- US, Sprint etc. sizing and estimation;
- progress control at any level.
What to do about NFR?

Again, there was no good standard definition of a NFR.

A joint COSMIC/IFPUG effort developed good definitions and a Glossary of NFR and Project Requirements.

The COSMIC Guideline advises how to deal with NFR.

Glossary of terms for Non-Functional Requirements and Project Requirements used in software project performance measurement, benchmarking and estimating

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Abran & Al Sarayreh showed that requirements that appear as NFR may evolve into FUR, that the COSMIC method can measure.
Examples of NFR leading to FUR with COSMIC
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COSMIC data from Industry

Practical experimentations with the COSMIC method in Automotive embedded software field

By: Sophie Stern

Renault
Renault – 2012

BCM: New developments, automatic coding
n=8

Effort

Functional size = CFP

R² = 0.8624

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Renault – 2012

BCM: New developments, manual coding
n=6

R² = 0.9311
Engine Control Unit: Modules evolutions, manual coding

$n = 28$

$R^2 = 0.804$

Effort (man/day)

Functional size = CFP
Renault: Estimation & Negotiations

BCM RFQ: COSMIC predictions versus Supplier estimations

© Copyrights Renault 2012
Renault - Remarkable cost estimation accuracy from its ECU software specifications

Cost vs size (CFP)

Memory size vs software size (CFP)
Case: Web effort estimation is more accurate with COSMIC than using classic FP

25 industrial Web applications

Conclusions:
‘The results of the ... study revealed that COSMIC outperformed Function Points as indicator of development effort by providing significantly better estimations’

Ref.: ‘Web Effort Estimation: Function Point Analysis vs. COSMIC
Sergio Di Martinoa, Filomena Ferruccib,*, Carmine Gravinob, Federica Sarroc
Information and Software Technology 72 (2016) 90–109

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Case: A Canadian supplier of security and surveillance software systems

- Uses Scrum method
- Teams estimate tasks within each iteration in Story Points, and convert directly to effort in work-hours
- Study involved measurements on 24 tasks in nine iterations
  - Each task estimated in Story Points - Effort;
  - Task actual effort recorded
  - Each task also measured in CFP

Effort vs Story Points (24 tasks) = a poor predictor of effort

Effort = 0.47 x Story Points + 17.6 hours and $R^2 = 0.33$
Effort vs COSMIC size is good for estimating

\[ Y = 2.35 \times \text{CFP} - 0.08 \text{hrs} \quad \text{and } R^2 = 0.977 \]

As a result of COSMIC measurement: two tasks were identified with very low effort/CFP. These were found to involve significant software re-use, so were considered separately.

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A User view of ‘COSMIC for Agile’

- “We have found that adopting this approach provides us with excellent predictability and comparability across projects, teams, time and technologies.”

- The reality of achieving predictable project performance has driven me to investigate many methods of prediction. COSMIC is the method that lets me sleep at night.”

Denis Krizanovic, Aon Australia, August 2014
Case Study – Vector (Germany):
Estimating Maintenance Effort

\[ \text{Size}_\text{FP} \text{ (Change)} = \text{size(added data)} + \text{size(modified data)} + \text{size(deleted data)} = 7 \]
Case Study – Vector (Germany): Maintenance Constraints

- **Requirements and design specification:** Consistent level of documentation
- **Modeling:** Same method, notation, semantics and visibility
- **Change documentation:** All changes are covered and clearly marked

Diagram:
- Functional change request
  - SW requirements analysis
  - SW architecture design
  - SW module design
  - SW module implementation
- SW validation before delivery
  - SW integration and integration test
  - SW module test

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Case Study – Vector (Germany): COSMIC Benefits

- Agreed model for measuring functional size
- Solid baseline for benchmarking
- Transparent effort estimations on the basis of functional changes
- Ad-hoc & fuzzy evaluations and negotiations for single SW changes are reduced
- Significantly increased efficiency & trust for better collaboration between supplier & customer
Case Study – Vector (Germany):

Results

- Vector achieved with many clients a preciseness of 10-20% within one year of building the estimation program.

- Consider business impacts
  - Clearly distinguish goals, estimates & plans
  - Challenge results & improve your efficiency each year
  - Don’t stay with same parameters for over 1 year.

- Establish repeatability
  - Immature processes invalidate your overall estimation & ruin trust
  - Establish a robust process to report & store data
  - Insufficient data quality & environmental constraints need experienced counting to avoid errors & weakening the method.
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COSMIC specifications for Automation with Matlab-Simulink


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Runnables inside the software components - Steer-by-Wire system

When Requirements are described with Graphs: Map to COSMIC

### TABLE I.

<table>
<thead>
<tr>
<th>COSMIC concepts</th>
<th>COSMIC abbreviation</th>
<th>Proposed graphical representation</th>
<th>Proposed graphical description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional user</td>
<td>FU</td>
<td><img src="image" alt="Green dashed box" /></td>
<td>Green dashed box</td>
</tr>
<tr>
<td>Functional process</td>
<td>FP</td>
<td><img src="image" alt="Blue box" /></td>
<td>Blue box</td>
</tr>
<tr>
<td>Data group movement</td>
<td>E/X/W/R</td>
<td><img src="image" alt="Black arrow" /></td>
<td>Black arrow</td>
</tr>
<tr>
<td>Persistent storage</td>
<td><img src="image" alt="data Store" /></td>
<td><img src="image" alt="ISO 5807 stored data symbol in light blue" /></td>
<td>ISO 5807 stored data symbol in light blue</td>
</tr>
</tbody>
</table>
COSMIC representation of functional process (Single & Many) – For testing scenarios
3-Phase Verification Protocol of Automation Accuracy

**Phase 1**

- Do the final results match?
  - Yes: Continue verifying the measurement in detail?
  - No: End of evaluation. High-level verification.

**Phase 2**

- Same number of FPs?
  - Yes: Difference caused by human error?
  - No: Same data movements in both measures?
    - Yes: End of verification. Detailed verification.
    - No: Same identified FPs in both measures?
      - Yes: Inspection of the quality of the specification.
      - No: Inspection of the tool’s modules.

**Phase 3**

- Defect quality or bug report?
  - Yes: Attempt to correct the bug or defect.
  - No: End of verification. Detailed verification.

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# Automation Accuracy Reached with COSMIC

<table>
<thead>
<tr>
<th>Steer-by-Wire Runnable</th>
<th>Functional size obtained by the manual FSM procedure (CFP)</th>
<th>Functional size obtained by the automated FSM procedure (CFP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steer_Run_Acquisition</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Steer_Run_Sensor</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Steer_Run_Command</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Steer_InterECU_Wheel</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Steer_Run_Actuator</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Wheel_Run_Acquisition</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Wheel_Run_Sensor</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Wheel_Run_Command</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Wheel_InterECU_Wheel</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Wheel_Run_Actuator</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Number of Models</th>
<th>Total Size obtained manually (CFP)</th>
<th>Total Size obtained using the prototype tool (CFP)</th>
<th>Difference (%)</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>76 fault-free models</td>
<td>1,729</td>
<td>1,739</td>
<td>Less than 1%</td>
<td>&gt;99%</td>
</tr>
<tr>
<td>All 77 models</td>
<td>1,758</td>
<td>1,791</td>
<td>1.8%</td>
<td>&gt;98%</td>
</tr>
</tbody>
</table>

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The COSMIC method is very widely used

- COSMIC Measurement Manual standard (11 languages)
- Size of user base is unknown
  - Of known users, 50% are software houses
  - Adopted by two Governments (Mexico, Poland)
  - > 30,000 downloads of research & conference papers
- + 600 certification exam holders (notably Brazil, China, India, Italy, Poland, Turkey)
- Two active forums (on LinkedIn CUG, www.cosmic-sizing.org)
Summary of benefits

- Free, open
- Fundamental SE Principles: future-proof, stable
- Very wide applicability
- Proven value for performance measurement & estimating
- ISO standard & GAO¹, NIST² endorsed
- Can be automated with very high accuracy & traceability

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Thank you for your attention

(www.cosmic-sizing.org)

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